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Container-breeding mosquitoes and predator community dynamics along an urban-forest gradient: The effects of habitat type and isolation

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Abstract

Environmental disturbances such as deforestation, urbanization or pollution have been widely acknowledged to play a key role in the emergence of many infectious diseases, including mosquito-borne viruses. However, we have little understanding of how habitat isolation affects the communities containing disease vectors. Here, we test the effects of habitat type and isolation on the colonization rates, species richness and abundances of mosquitoes and their aquatic predators in water-filled containers in northwestern Thailand. For eight weeks water-filled containers were monitored in areas containing forest, urban and agricultural habitats and mixtures of these three. Mosquito larvae of the genera *Aedes* and *Culex* appeared to be differentially affected by the presence of the dominant predator; *Toxorhynchites splendens* (Culicidae). Therefore, a predation experiment was conducted to determine predator response to prey density and its relative effects on different mosquito prey populations. Colonization rates, species richness and abundances of mosquito predators were strongly related to forest habitat and to the distance from other aquatic habitats. Areas with more tree cover had higher predator species richness and abundance in containers. Containers that were close to surface water were more rapidly colonized than those further away. In all habitat types, including urban areas, when predators were present, the number of mosquito larvae was much lower. Containers in urban areas closer to water-bodies, or with more canopy cover, had higher predator colonization rates and species richness. *T. splendens* (Culicidae) preyed on the larvae of two mosquito genera at different rates, which appeared to be related to prey behaviour. This study shows that anthropogenic landscape modification has an important effect on the natural biological control of mosquitoes. Vector control programmes and urban planning should attempt to integrate ecological theory when developing strategies to reduce mosquito populations. This would result in management strategies that are beneficial for both public health and biodiversity.

Zusammenfassung

Störungen der Umwelt, wie Abholzung, Verstädterung oder Umweltverschmutzung werden weithin als Schlüsselfaktoren für das Auftreten von ansteckenden Krankheiten, einschließlich der von Stechmücken verbreiteten Viren, angesehen. Indessen wissen wir wenig darüber, wie die Isolation von Habitaten die Gemeinschaften beeinflusst, die Krankheitsvektoren enthalten. Hier

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untersuchen wir die Effekte von Habitat-Typ und Isolation auf die Besiedelungsraten, den Artenreichtum und die Abundanzen von Stechmücken und deren Räubern in Wasserbehältern im nordwestlichen Thailand. Acht Wochen lang waren die Behälter in Betrieb, in Gebieten mit Wald, bebauten Flächen, landwirtschaftlichen Flächen und Mischungen der drei Habitat-Typen. Die Larven der Stechmückengattungen *Aedes* und *Culex* schienen unterschiedlich von der Anwesenheit des dominanten Räubers; *Toxorhynchites splendens* (Culicidae) beeinflusst zu werden. Deshalb führten wir ein Experiment durch, um die Reaktion des Räubers auf die Beutedichte und seine Effekte auf unterschiedliche Stechmücken-Beutepopulationen zu bestimmen. Die Besiedelungsraten, der Artenreichtum und die Abundanzen von Stechmückenräubern waren stark mit dem Habitat-Typ Wald und der Entfernung zu anderen aquatischen Lebensräumen verknüpft. In Gebieten mit hohem Waldanteil waren Artenreichtum und Abundanz der Räuber höher. Behälter, die sich in der Nähe von Oberflächengewässern befanden, wurden schneller besiedelt als weiter entfernte. In allen Habitat-Typen, einschließlich der urbanen Gebiete, war die Zahl der Stechmückenlarven geringer, wenn Räuber anwesend waren. Behälter in urbanen Gebieten in Gewässernähe oder mit höherer Baumbedeckung wurden schneller besiedelt und enthielten mehr Räuberarten. *T. splendens* (Culicidae) erbeutete die Larven von zwei Stechmückengattungen unterschiedlich schnell, was mit dem Verhalten der Beutetiere zusammenhängen könnte. Diese Untersuchung zeigt, dass anthropogene Veränderungen der Landschaft wichtige Auswirkungen auf die biologische Kontrolle von Stechmücken haben. Vektorkontrollprogramme und Stadtplanung sollten versuchen ökologische Theorie bei der Entwicklung von Strategien zur Bekämpfung von Stechmückenpopulationen zu integrieren. Dies würde zu Managementstrategien führen, die sowohl der öffentlichen Gesundheitsvorsorge als auch der Biodiversität nützen.

Keywords: Culicidae; Isolation; Predator–prey community; *Toxorhynchites splendens*; Vector ecology

Introduction

Environmental disturbances such as deforestation, urbanization or pollution have been widely acknowledged to play a key role in the emergence of many infectious diseases (Guerra, Snow, & Hay 2006; Yasuoka & Levins 2007; Patz, Olson, Uejio, & Gibbs 2008) through severe alterations to local hydrology, temperature and light regimes (Meher-Homji 1991; Culf, Esteves, Marques Filho, & da Rocha 1996). Water availability, temperature and light are strong drivers of the development of mosquitoes and the regulation of their population densities (Clements 1999). Thus, the effects of such environmental changes are particularly evident in mosquito-borne diseases. For example, the main mosquito vector of dengue fever, *Aedes aegypti* L. 1762, has been associated with urbanization and deforestation (Vanwambeke, Lambin, Eichhorn, Harbach, Oskam, et al. 2007; Cox, Grillet, Ramos, Amador, & Barrera 2007) and malaria and its vectors have also been positively related to deforestation in South America and Africa (Overgaard, Ekbom, Suwonkerd, & Takagi 2003; Yasuoka & Levins 2007).

Deforestation and urbanization not only affect mosquito populations, but also those of their predators (Samways & Steytler 1996; Lundkvist, Landin, & Karlsson 2002; Carlson, Keating, Mbogo, Kahindi, & Beier 2004; Cox et al. 2007; Fischer & Schweigmann 2008). For example, Carlson et al. (2004) showed that these predators are less likely to colonize water bodies in urban environments. Several studies have also shown that habitat isolation strongly affects the composition of freshwater invertebrate communities (Shulman & Chase 2007); Chase & Shulman 2009). An increase in mosquito predators can have a strong effect on the population density of mosquitoes, and many aquatic predator species are known to strongly suppress the abundance of mosquitoes (Fincke, Yanoviak, & Hanschu 1997; Blaustein, Blaustein, & Chase 2005; Culler & Lamp 2009). Further, in the interests of disease vector control, it is important to understand how mosquito-predator communities may be affected by anthropogenically-altered landscapes.

Here, we present a study that compares mosquito-predator colonization and mosquito larval abundance along a gradient of urbanized and forest habitats. We investigated the effects of habitat type and isolation on the colonization rate of mosquitoes and predators in water-filled containers. We were particularly interested in *Aedes* mosquitoes, a genus of mainly container and tree-hole breeding mosquitoes which also contains all vector species of dengue fever (Clements 2012), and its predators. Theory predicts that (1) species richness increases when habitat patches within a matrix of unsuitable habitat increase in size and (2) colonization rates are higher when a habitat patch is nearer to a source habitat (MacArthur & Wilson 1967). For example, Caillouët, Carlson, Wesson, and Jordan (2008) investigated the colonization of mosquito larvae and their predators in flooded (swimming) pools. They found that predator species richness (fish) was negatively related to the distance from the source habitat. Shulman and Chase (2007) observed a similar pattern for invertebrates in an experiment with plastic tubs at different distances from three different source ponds. Mosquito predator richness was negatively related to the distance to the source ponds.

The effects of habitat fragmentation and isolation on predator–prey interactions are complex because they involve two or more interacting species and these factors may affect